alt. 5000 ft., July 1, 1934, *M. E. Peck 2593* (W); bank of Frog Lake, July 27, 1927, *M. E. Peck 15910* (W).

I wish to express my thanks to Dr. C. O. Rosendahl and Dr. F. K. Butters of the University of Minnesota for their counsel and suggestions given during the course of this investigation.

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## OBSERVATIONS ON THE WESTERN JUNIPER

Waldo S. Glock

A brief study of the western juniper (*Juniperus occidentalis* Hook.) in the high Sierra Nevada of Alpine and Tuolumne counties, California, has yielded some interesting information and has raised some important problems. The species was observed and core samples taken in Faith and Charity valleys southeast of Lake Tahoe, in the vicinity of Kit Carson Pass, and in the Sonora Pass and Dardanelles region. The writer's attention was directed to the juniper by Mr. Clarence K. Bennett and Dr. Ralph W. Chaney. Especial gratitude is due Mr. Bennett whose financial aid helped to make the field work possible.

Specific localities inhabited by the junipers are quite distinctive. These trees occupy relatively dry sunny slopes with westerly or southerly exposure. However, scattered trees were seen on a precipitous easterly slope whose individual jutting ledges of nearly bare granite provided sites which have approximately the same exposure time to the sun as have the westerly slopes. The junipers are most frequently found on gravel moraines, on slopes of coarsely weathered lava, or on bare granite ridges where their roots insinuate themselves with difficulty among the huge boulders and into crevices. Such habitats, rather than rich humus or moist meadow borders, are preferred.

In Faith Valley at an elevation just below 8000 feet, the trees grow upon a weathered lava slope and also upon the side of a gravel ridge. At Chipmunk Flat along Deadman Creek at an elevation of 8000 feet, they grow on a coarse boulder terrace fifteen to twenty-five feet above stream level. The north wall of Deadman Canyon, above Chipmunk Flat, rises to a bare granite shoulder and ridge at about 9000 feet. Here, scattered junipers,

low, squat, and grotesquely gnarled, maintain what appears to be a precarious foothold in the crevices. In the vicinity of lower Relief Creek at 6500 to 7000 feet and on the upland west of the mouth of Deadman Creek (Dardanelles Quadrangle, United States Geological Survey) at 8500 feet the junipers grow on rock ledges and on gravel knolls and ridges. Here, on what is called East Flange Ridge, they probably have their best development.

On the whole the western juniper, in contrast with its relatives, inhabits the subalpine zone at comparatively high elevations near timberline. The California juniper (*Juniperus californica* Carr.) and the desert juniper (*Juniperus utahensis* Lemmon) are commonly among the first trees encountered above the Lower Sonoran zone, whereas the western juniper is commonly among the last encountered at the upper tree limit. In habit, in form, and in age the two types differ remarkably. The high altitude species possesses a more highly developed arborescent form than its lowland kin; it is in certain cases regal in its proportions. Its vitality is such that although the stress of weather and the presence of rock fragments may distort and malform it into weirdly grotesque caricatures of trees, it survives the wrack and stress until the last bit of cambium dies.

Western junipers, on the whole, are not only solitary as a species but also solitary as individuals. They are intolerant of shade and of crowding. Where grouped, the trees are spaced openly much in the manner of the western yellow pine (*Pinus ponderosa* Dougl.). Many of the veterans stand completely isolated on a sunny slope or knoll. Close association with other species of trees is rather uncommon in the localities of this study. However, in the same general area red fir (*Abies magnifica* Murr.) and lodgepole pine (*Pinus Murrayana* Balf.) are the most frequent associates; and Jeffrey pine (*Pinus Jeffreyi* Murr.) is a poor third. A surprising fact observed at once on the upland west of the mouth of Deadman Creek was the nearly exclusive presence of large trees, juniper, fir, lodgepole and Jeffrey pine. Seedlings and saplings were practically non-existent.

Several points deserve mention in connection with the reasons why these junipers occupy such inhospitable sites and how they manage to exist. (1) The junipers do not seem able to exist in close association. From observation, however, it does not seem likely that they crowd out other species. More probably the latter cannot gain a foothold on certain locations. (2) The extraordinary vitality of the junipers permits them to live on what appears to be almost sterile granite or on coarse gravels deficient in large quantities of mineral nutrients. (3) In addition, these junipers possess remarkable regenerative powers. An injury must be serious indeed even to cripple a tree, much less to destroy it. Injuries which are mortal to less hardy species, such as pine and fir, or which shorten their lives to a marked

degree, may only deform the juniper. New wood may overlap a wound on the trunk so completely as to defy detection from the exterior. Root buttresses and multiple trunks become so closely compressed that the symmetry of the trunk is enhanced rather than lessened. Stumps and cores showed bark and decayed places where none would be expected from an exterior examination. Indeed, in some trees it was nearly impossible to secure an uninjured core eleven inches long. (4) A tree remains alive as long as a single root and branch function. It may be said that the junipers die by inches. Many specimens were seen which, save for one tuft of green, were gaunt gray skeletons. So numerous are the partially dead branches that one is tempted to say they are typical of all trees. The tops and sides of the main branches are commonly devoid of bark, dead, and deeply weathered. One-third or less of the girth of a branch, on the under side, may support bark, beneath which lies active cambium. One specimen showed only about 15 per cent of functioning wood. As a consequence of growth restricted to the under side, the branches are extremely eccentric, or hyponastic, and so much so that the vertical diameter may be three to five times the horizontal. (5) The ability to use soil moisture when it is available is an important feature that will be taken up in the discussion on the time of formation of the annual ring.

The western juniper merits distinction because of the size of its trunk and because of the great age attained by its individuals. Trees whose diameters range from four to eight feet are very common. On the Kit Carson road several miles west of Kit Carson Pass, the Forestry Service has erected a sign reading "California's Largest Juniper" near a tree which is stated to be 31 feet 8 inches in circumference. However, since it is a triple-trunked tree its age cannot be as great as this circumference would indicate. Several large specimens were measured at a height of five or six feet above ground on the upland west of the mouth of Deadman Creek. One, whose trunk is a single shaft, has a circumference of 27.5 feet. A second, triple-trunked above, has a circumference of 31 feet.

As a species the western juniper ranks well above its common associates in the matter of longevity. Trees five and six feet in diameter are not at all uncommon and those from which core samples were taken gave evidence of being between 900 and 1000 years old. The longevity of the species certainly equals that of the coast redwood and in a few instances rivals that of the giant sequoia. Perhaps it is significant that the sequoia, the juniper, and the bald cypress of Oaxaca, Mexico, all long-lived trees, belong to kindred families. These genera have tremendous durability of their woods coupled with vigorous tenacity of life and regenerative powers.

The Bennett Juniper, a magnificent specimen, with a single stately trunk approximately eighty feet high, is the giant of all those so far observed by Mr. Clarence K. Bennett[1] of Hillsborough, California, who has studied and hunted the juniper for many years. It stands on the upland west of the mouth of Deadman Creek, a tributary of the Middle Fork of the Stanislaus River. The dimensions of this large juniper are as follows:

| | | | | |
|---|---|---|---|---|
| Circumference at ground ..... | 57 | feet, | 6.5 | inches |
| Circumference six feet above ground .. | 42 | " | 9 | " |
| Greatest diameter at ground ..... | 21 | " | 6 | " |
| Average diameter five feet above ground | 14 | " | 2 | " |

The diameter for working purposes may be taken as 13.5 to 14 feet.

It is highly appropriate that this monarch among junipers be named "The Bennett Juniper," not that Mr. Bennett was the first to see it (hunters saw it previously), but because he was the first man to take a lively sustained interest not only in the giant but also in all junipers of its kind wherever he has been able to find them in the high Sierra Nevada.

From the two or three stumps noted it was surmised that in this region the species has yielded but little to the saw commercially. Age, therefore, had to be determined wholly from cores which were obtained from trees of different diameters. Usually several cores, varying in length from six to fifteen inches, were taken from each tree. In computing age, due allowance must be made for increasing width of rings toward the center of the tree. This increase, however, is not nearly so striking as in the pine. All cases actually observed showed thinner rings at the center than several inches outside the center and in no case was there a uniform increase in width inward from the bark. Nevertheless, ample allowance for the "age curve" was made in order to keep estimates on the conservative side.

The age of the Bennett Juniper was computed in three ways, in the first two of which synthetic trees were built up by the substitution of progressively smaller trees for the inside of the big tree. For the first trial, four trees from the same upland which supports the big tree were united with five specimens from the big tree itself. The four trees included four cores from an 8.5-foot tree, three cores from a 4.5-foot tree, one core from a 27-inch tree, and a section of a 6-inch tree. The rings in the spaces between the cores and the next smaller tree were computed by interpolation. In round numbers, the age of the Bennett Juniper came out as 2900 years.

Entirely new material gave the basis for the second estimate. Seven cores, the longest fifteen inches, were taken from the big

[1] Clarence K. Bennett. The largest juniper? Sierra Club Bulletin 18: 115–116. 1933.

PLATE VII. THE BENNETT JUNIPER (JUNIPERUS OCCIDENTALIS HOOK.).

juniper at about equal intervals around the trunk, save for the northwest where there was some dead wood. These cores averaged more than seven hundred rings to the first foot of radius. Two trees from Charity Valley, one 8 feet and the other 5 feet in diameter, were inserted for the interior of the large tree. The first foot of the 8-foot tree had 476 rings and the first foot of the 5-foot tree had 510 rings. By computation and interpolation the age of the Bennett Juniper came out to be 3250 years.

The third estimate of age was based on the ring counts in the seven cores. Ring counts were plotted and the smooth curve drawn through the plotted points was continued inward to the center of the tree. The age so computed averaged 3000 years or slightly more.

From the data at hand, a fair estimate, in round numbers, of the age of the Bennett Juniper is 3000 years. There can be little doubt that the tree is well over 2000 years old, since the outer foot of the trunk averages seven hundred rings. The age curve would have to be steeper than any observed in other trees in order to hold the age below 2000 years. It may well be that the age is distinctly more than 3000 years, but until the entire stump is visible the exact age will not be known.

Two interesting problems that merit comment arose during the study of the western juniper: (1) circuit uniformity; (2) time of ring formation.

Circuit Uniformity. Annual rings are said to possess circuit uniformity if their relative thicknesses remain constant around the entire circumference. A juniper 19 feet high and 6.5 inches in diameter six feet above ground was felled on the upland west of the mouth of Deadman Creek, about seventy-five yards from the Bennett Juniper and up slope from it. None of the half dozen sections taken at different heights shows a high degree of circuit uniformity. In fact three or four rings show unusual thickening at one place on the circumference and groups of several other rings at other places. Few rings are uniformly thicker or thinner than their adjacent neighbors. This being true, it is to be expected that difficulty must attend the attempt to match rings in different trees or in different radii of the same tree. However, a few isolated cases of such matching, or cross-dating, were detected at this elevation.

The lack of perfect uniformity in the western juniper resembles somewhat that described by Shreve[2] for the Monterey pine (*Pinus radiata* Don), save that in the case of this single juniper vertical uniformity appeared to be better developed than circuit uniformity. On the other hand, extensive and detailed studies have shown remarkable uniformity in certain species, especially the western yellow pine of the southern part of the Colorado

[2] Forrest Shreve. The growth record in trees, Carnegie Inst. Wash. Pub. No. 350, 91–116. 1924.

Plateau. Is ring uniformity an environmental or a specific character?

Time of Ring Formation. In the case of the 19-foot juniper, on July 5, when snow had been off the ground less than two weeks, the ring for 1936 was one-third to one-half the thickness of the previous ring, or about equal in thickness to the average ring. Tip growth already exceeded three inches. Cores taken at the same time from junipers at the same locality and at Chipmunk Flat showed rings for the current season of one-tenth to more than one-half the average thickness of the last six rings. A lodgepole pine had grown a ring more than three-fourths the thickness of the average for the last six rings. Four cores from Digger pines (*Pinus Sabiniana* Dougl.) which grew six miles southwest of Sonora in the lower foothills gave evidence that their seasonal growth was practically completed by July 6. In at least two cases summer wood had been formed. Cores taken from the Bennett Juniper on August 7 possessed what seemed to be practically complete rings for 1936. The same was true for the junipers from Charity Valley. A lodgepole pine from the vicinity of the Bennett Juniper had its growth nearly completed but neighboring Jeffrey pines were a trifle behind in their growth. Lodgepole pines from Hope Valley had just begun the formation of summer wood as had also western yellow pine from Walker Canyon (6200 feet) near Sonora Pass Junction. Two lodgepole pines from Sonora Pass at 9650 feet elevation were beginning the formation of summer wood. Judgment as to the completeness of the annual ring was made not alone upon the amount of wood in relation to previous rings but also upon the two following criteria: diminution of cell size and deposition of dark materials on cell walls. In the Digger pines and one western yellow pine from Walker Canyon dark color had appeared. Certainty of the correct identification of cellular division for 1936 was enhanced by cross-dating, that is, the matching of characteristic rings from one tree to another.

In connection with the above observations three points have considerable significance. (1) Growth must certainly begin in the high-altitude trees here studied before the snow leaves the ground. (2) The evidence indicates that a considerable part (more than half in some cases) of the seasonal growth is completed within two weeks after the snow has melted. This applies in particular to the locality of the Bennett Juniper on the west end of East Flange Ridge. Where the water supply is unquestionably greater, as is the case for the trees at Chipmunk Flat, there are indications that growth was less than at the previously mentioned locality. Both Chipmunk Flat and East Flange Ridge are so situated that they no doubt receive cold air drainage, but the former much more so than the latter. (3) The time of maximum ring formation early in the season, before temperature has reached a maximum and before water supply has diminished to a

serious extent, has important climatic significance. If the observations so far made are valid, then the length of the so-called growing season as based upon the interval during which temperatures are supposed to be advantageous for growth has little influence on the thickness of the annual ring. Apparently the trees must make their growth while water is available. If it is available all summer, growth continues for a longer time; but if water is dependent upon winter precipitation and receives no replenishment later, growth ceases sooner or later during the summer according to the availability of the water. The Digger pine from the foothills below Sonora was the most advanced in growth of all trees from which core samples were taken on July 5 and 6.

Such evidence as has been obtained suggests that the time of ring formation constitutes a problem which deserves study by taking core samples periodically during an entire growing season of trees from the lower forest border up to timber-line. The presence in any particular area of trees which depend solely upon winter precipitation has a climatic and ecologic significance different from the presence of those which depend upon a summer rainy season.

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## A NEW SPECIES OF CHAETOMORPHA FROM CHINA

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On a recent visit to the California Academy of Sciences in Golden Gate Park, San Francisco, my attention was called by Dr. F. M. McFarland, President of the Academy, to a small tortoise which had been recently asquired through the generosity of Princess Olga Shahovski, who had brought it from China. Its back was densely covered with "green hair," so popularly designated. Such a symbiotic relationship, if such it may be called, is of very rare occurrence in western America, if indeed it has ever been observed and reported among our native species. However, it has been reported several times as occurring in the eastern part of the United States, and apparently is of common occurrence in parts of China and Japan. Wang (5) states that the "green haired tortoise" has been a well known animal in the provinces of Changshu, Kiangsu, and in the northern part of Yushan. In China the "green hair" grows on relatively small species of tortoise. These of course are not of the basking kind, and on account of the popular interest which they create in domestic aquaria they are commercialized to considerable extent.

The specimen in the public aquarium at the California Academy rarely fails to excite the interest and curiosity of visitors, often calling forth strange expressions indicative of total igno-